A focusing-device for the radiation from a light source

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to a focusing-device for the radiation from a light source, in particular a laser plasma source, having a collector mirror according to the preamble of claim 1 of a type defined more closely.

An illuminating system having a collector mirror is described in US 5,798,823.

2. Description of the related Art

In semiconductor lithography, use is frequently made of a light source, for example a laser plasma source, whose light is collected, in virtual or real terms, via a collector mirror at a second focus, and then guided for beam formation into an illuminating system. The collector mirror is heated by the laser plasma source, resulting in corresponding changes in shape which have negative effects on the downstream illuminating system such as, for example, illumination defects, for example telecentring errors, uniformity defects, and this can lead to light losses.

It is known for the purpose of avoiding these disadvantages to cool the collector mirror in order to dissipate the heat produced. Irrespective of the large outlay required for this purpose, because of unavoidable tolerances problems continue to exist, nevertheless, with reference to the imaging accuracy, and these are to be ascribed, inter alia, to a change in position of the second focus. In addition, given high thermal loads, which can vary strongly with time in the case of pulsed operation, the collector mirror cannot be kept

entirely at a constant temperature level, and so would necessitate a "dynamic" cooling system.

SUMMARY OF THE INVENTION

It is the object of the present invention to create a device in the case of which the disadvantages of the prior art are avoided, in particular in the case of which the optical properties of a collector mirror are maintained in an unchanged form even under thermal loading such that no negative effects on the downstream illuminating system occur.

According to the invention, this object is achieved by means of the features claimed in the characterizing part of claim 1.

By virtue of the fact that the collector mirror is specifically displaced in the z-direction, that is to say in the direction of the optical axis, and that the collector mirror itself is designed in such a way that the position of the second focus remains unchanged in the event of temperature change, the optical properties of the collector mirror are maintained in an unchanged form even under thermal loading.

It is proposed according to the invention in a first design solution to mount or configure the collector mirror such that its shape is formed in accordance with an isofocal family of curves, for example a family of ellipses, a family of hyperbolas or a family of parabolas. What is meant by an "isofocal" family of curves is that the spacing from the source, that is to say from the first focus to the second focus, does not change. Only a family of ellipses will be spoken of below, for the sake of simplification. An isofocal family of ellipses projects a source into a fixed image of the source. If the collector mirror is now shaped under heating in accordance with the isofocal family of el-

lipses, its optical properties remain constant. This means that it is then no longer necessary to cool the collector mirror, or to keep it at a constant temperature, by means of a high outlay, but that heating is permitted while ensuring, however, that the change in shape of the collector mirror resulting therefrom takes place such that selected optical properties remain unchanged.

For such an isofocal collector mirror, the conic constant K and the semiparameter p = R can be represented to a good approximation by linear functions of the intercept distance between the source and the vertex of the collector mirror.

If, on the other hand, the aim is to avoid a change in magnification, normally negligible per se, owing to a change in or displacement of the collector mirror, the spacing from the source to the imaging plane of the light source must be varied as second solution. This can be performed, for example, actively or else via a passive thermal expansion. The eccentricity γ or conic constant K must remain constant for such a collector mirror which contains magnification, and the vertex curvature p = R must change linearly. This solution is advantageous in some circumstances for a system with critical illumination, because then the image of the light source remains the same size on the reticule.

By contrast with the solution using the isofocal family of curves, where the spacing between the first and the second focus remains the same, in this alternative solution the beam angle from the collector mirror to the second focus remains the same, the second focus thereby being displaced correspondingly. If the second focus is to remain at the same point, it follows that not only the collector mirror must be moved correspondingly in the z- direction, but also the source or the first focus.

Since collector mirrors are generally subjected to an anisotropic thermal loading, it may be provided in a refinement according to the invention that the collector mirror is provided with inhomogenously distributed cooling devices in such a way that an at least approximately uniform temperature distribution is achieved in the collector mirror. Although this does entail a higher outlay, by comparison with known cooling devices, however, this outlay can be kept markedly lower, because there is no need to carry out an entire cooling of the collector mirror, but only to ensure a largely uniform temperature distribution.

Instead of a collector mirror which operates by reflection, it is possible in a very advantageous refinement of the invention also to support in the inventive way a collector mirror which, as a so-called transmitted-light collector, has a plurality of nested annular shells or mirror shells which are jointly fastened on a mount. Such transmitted-light collectors, also termed shell collectors, are also denoted as "nested collectors" (see, for example, EP 1 225 481 A2 and DE 101 38 284 A1). In use, a shell collector exhibits strong heating, and this results in deformation of the collector mirror owing to temperature gradients and/or different coefficients of thermal expansion of the components used. This applies, in particular, in the bearing regions of the annular shells to the mount which is generally designed as a mounting ring or spoked ring having a plurality of spokes which run in a radial direction and on which the individual annular shells are fastened at an appropriate radial spacing from one another.

The imaging of the source at the secondary focus is effected by the geometry of the mirror shells. Any change in this geometry leads to a change in the image. During operation and as a result of the operating conditions

(EUV radiation and vacuum) the collector is strongly heated and can reach a temperature of several hundred degrees Celsius. The selection of the material lends the annular cells a specific coefficient of thermal expansion (CTE), and likewise the mounting ring. Deformations come about at the collector since there is a temperature gradient across the annular shells and the mounting ring and thus as a result of: $\Delta L = L*CTE*\Delta T$ (L = length, ΔL = change in length, T = temperature and ΔT = temperature deviation) differently observed points on the mounting ring and the annular shells expand differently. These deformations are extremely large, particularly at the joints between the annular shells and mounting ring since the largest temperature gradients in the system occur here, depending on the joining method. This means that because, for example, of a higher temperature level the collector would like to expand more at the clamping point than the mounting ring. Since the mounting ring has the higher degree of stiffness, the expansion of the annular shells at this point is suppressed. However, the shells can expand without hindrance at the non-clamped points. As a result of this, given clamping points with a distribution of 4 × 90°, for example, the collector is formed like a clover leaf, since the mounting ring suppresses expansion at the four clamping points, whereas expansion is possible at four points offset by 45°. The abovedescribed asymmetrical deformation of the collector cannot be corrected or can be corrected only with a large outlay.

According to the invention, the connecting points or clamping points of the annular shells on the mounting ring or the ribs can be selected such that the annular shells can expand symmetrically with reference to the optical axis. The mirror collector leads in this way to a symmetrical change in shape by comparison with the cold state. This symmetrical change in shape, and the

changes, possibly associated therewith, in the optical imaging of the system can then, if required, be compensated without major problems. If the annular shells of the mirror collector are supported on one side or in a floating fashion in the mounting ring, for example at one end, and if thereby the other end is not clamped in, the free end can expand correspondingly in the direction of the optical axis. All that is then required at the clamping points is to permit movements and/or displacements of the annular shells in the radial direction or perpendicular to the optical axis. The annular shells can be connected to the mounting ring on the side diverted from the light source, or be connected to the mounting ring at any desired site between the two ends.

Both passive and active systems, and also combinations of the two, can be used to enable displacement of the annular shells in a radial direction. In the case of passive systems, it must be ensured that the stiffness at the clamping point is not too greatly reduced. Active systems offer the possiblility of a higher degree of stiffness at the clamping point, but it is then necessary to provide separate adjusting elements which are to be actuated from outside.

Parallelogram guides for the annular shells or for bearing parts in which the annular shells are held are, for example, possible as passive or else active systems. Likewise possible are pulling wires or push rods in the strengthening ribs, which pull or push the bearing parts appropriately into a desired position. Linear guides with slide or ball bearings in the form of telescopic changes in length are also conceivable.

A further possible connection of the annular shells to the mounting ring or the strengthening ribs consists in making use for this purpose of leaf springs which are either formed integrally in the circumference of the

annular shells or are arranged as separate parts on the circumference of the annular shells. The leaf springs can in this case run both in the direction of the optical axis and in the circumferential direction of the annular shells.

Also conceivable as semi-active systems are actuators which react to temperature changes. In this case, the annular shells or their bearing parts are connected to the mounting ring via a "thermal actuator". The "thermal actuator" is designed in this case with reference to its length and its coefficient of thermal expansion in such a way that annular shells or their bearing parts are displaced in the event of temperature changes such that the optical properties of a collector mirror do not change or change only to a correctable extent.

BRIEF DESCRIPTION OF THE DRAWINGS

Design configurations for specifically carrying out the change in shape of the collector mirror in the desired way are explained schematically in principle in the subclaims and in the exemplary embodiments described below diagrammatically with the aid of the drawing, in which:

figure 1 shows a schematic illustration of a collector mirror according to the invention which is arranged in an EUV illuminating system for microlithography, in a first embodiment;

figure 2 shows a representation of the principle of the travel path of the radiation between the collector mirror and the second focus, for an isofocal family of ellipses;

figure 3 shows a representation of the principle of the travel path of the radiation between the collector mirror and the second focus, for

maintenance of the magnification;

figure 4 shows a first type of bearing for the isofocal collector mirror according to the invention;

figure 5 shows a bearing of an isofocal collector mirror with a bending spring;

figure 6 shows a bearing of an isofocal collector mirror with active components;

figure 7 shows a bearing of an isofocal collector mirror with an additional variation in spacing in the event of temperature increase;

figure 8 shows a bearing for an isofocal collector mirror with a reduced change in position in the event of temperature increase;

figure 9 shows a bearing of an isofocal collector mirror in a mount via a parallelogram guide;

figure 10 shows a collector mirror in a second embodiment in the form of a shell connector with a multiplicity of annular shells, in a side view of the principle;

figure 11 shows the shell collector according to figure 10, in a perspective view;

figure 12 shows the top view of the mounting ring of the shell collector according to figure 10;

figure 13 shows a schematic illustration of a bearing of an annular shell on the mounting ring in a section along the line XIII-XIII according to figure 12;

figure 14 shows an embodiment of a bearing of an annular shell on the mounting ring in a similar configuration to figure 13;

figure 15 shows a third embodiment of a bearing of an annular shell in the mounting ring with a linear guide;

figures 16 to 18 show a bearing of an annular shell in the mounting ring via a leaf spring which is integrally formed or incorporated into the annular shell;

figures 19 and 20 show a bearing via a leaf spring, similar to the bearing according to figures 16 to 18, the leaf spring being designed as a separate part;

figures 21 to 23 show a bearing of an annular shell in the mounting ring via a leaf spring, in a configuration similar to that illustrated in figures 16 to 18, with a radially applied leaf spring;

figure 24 shows the leaf spring illustrated in figures 21 to 23, as a separate part attached to the annular shell;

figure 25 shows a semi-active adjusting system for an annular shell by means of an actuator which changes with heat; and

figure 26 shows an illustration of the principle of a bearing of an annular shell on the mounting ring, the displacement being performed by an active system.

DETAILED DESCRIPTION

Illustrated in figure 1 as an example for a possibility of use is a collector mirror 1 which behaves isofocally and is integrated in an illuminating system for the purpose of fabricating semiconductor elements for EUV lithography.

The light from a source 2, for example a laser plasma source or a pinch plasma or dense plasma focus, is projected onto a facet mirror 3 via the collector mirror 1. The source 2 is situated at the first focus of the collector mirror 1. In the exemplary embodiment illustrated, the second focus 200 (not illustrated in figure 1) is situated downstream of the facet mirror 3. The light is fed from the facet mirror 3 to a reticule (mask) 5 via a deflecting mirror 4. The structure of the reticule 5 is led to a wafer 7 for projecting via a projection lens 6(not shown in any more detail).

The laser plasma source 2 subjects the collector mirror 1 to a high thermal load which changes its shape. This change in shape would normally lead to uncontrolled illumination defects.

Figure 2 now shows a representation of the principle of a controlled change in shape and displacement of the collector mirror 1 such that the optical properties of the collector mirror are maintained. This illustrates a solution in which the collector mirror 1 is specifically displaced in the z-direction, and its shape is changed in accordance with an isofocal family of curves, in such a way that the second focus remains unchanged with reference to its position.

To a good approximation, the parameters ε and p describing the family of ellipses can be represented as a linear function of the temperature change dT. It there-

fore holds that:

$$p \approx s_0\left[\ (1+\varepsilon_0)+\alpha\left\langle 1+\varepsilon_0-\frac{s_0\varepsilon_0}{a_0}\ \right\rangle dT\ \right]$$

It holds in this case that:

p = semiparameter

2e = focal point spacing

s_0 = distance from the source to the vertex of the collector mirror

$a_0 = e + S_0$ and $S\ (dT=0) = S_0$

It holds for the intercept distance = distance from the source to the collector mirror that:

$s = a - e$

α = coefficient of linear expansion of the material used, and

ε = numerical eccentricity of the ellipse

γ_2 = aperture angle of the radiation between the second focus and the collector mirror.

As may be seen from figure 2, the focal point spacing 2e is maintained, and it is only the angle γ_2 which changes into γ_2' and S_0 changes into S(dT).

Figure 3 shows the representation of the principle of a solution, the collector mirror being designed in such a way that the magnification, that is to say the image scale or the aperture on the image side, does not change under thermal loading. The distance from the source 2 to the image of the light source must be varied for this purpose. The eccentricity ε or the conic constant K must remain constant for this magnification-maintaining collector, and the vertex curvature p = R must change linearly. It follows from this for the semiparameter p that:

p =

$$s \cdot (\varepsilon + 1) = s_0 \cdot (1 + \alpha \cdot dT) \cdot (\varepsilon + 1) = p_0 \cdot (1 + \alpha \cdot dT)$$

where aperture of the source p_0

aperture of the beam $p_1 = \sin\gamma_2 = \dfrac{\sin\gamma_1}{\beta_c}$

magnification of the collector β_c = const.

As may be seen from figure 3, in this case the focal point spacing 2e also changes into 2e′, which means that the source 2 is displaced toward 2′. As may be seen, the aperture angle γ_2 is maintained in this case. Instead of a displacement of the source 2, it would also be possible in principle for the second focus to be displaced with the same result, in order to keep the angle γ_2 the same. In practice, however, the second focus will be kept fixed and the source 2 and collector mirror 1 will be displaced appropriately in the z-direction.

Of course, it is also possible to use families of hyperbolas or parabolas instead of families of ellipses.

The collector mirror 1 is designed in accordance with the set requirements such that it behaves when heated in a fashion which is isofocal or, alternatively, maintains the magnification. This means that a specific change in shape is permitted in such a way that its shape changes accordingly. The most varied design refinements are possible in order to achieve this shaping. The exemplary embodiments described below only schematically with the aid of figures 4 to 9 are therefore to be regarded only by way of example. They relate to an isofocal collector mirror 1. It is true that, given an appropriate design configuration of the collector mirror 1, its suspension and, if appropriate, its cooling, there is likewise a change in the shape of the collector mirror 1, but this is done specifically

in such a way that specific desired optical properties remain unchanged, however.

In accordance with the exemplary embodiment according to figure 4, the collector mirror 1 is connected at the circumference to a mount 10 via bearings 9 which can be displaced at right angles to the optical axis 8, that is to say to the z-axis (optical axis). Upon heating, the collector mirror 1 expands and the bearings 9 can be displaced - in accordance with the temperature - in the direction of the arrow 11 (see dashed illustration of the collector mirror 1). At the same time, the collector mirror 1 is moved rearward or away from the source 2 in a central guide 12 against the resistance of a spring device 13. As may be seen, this results in a change in spacing Δa_1 between the source 2 and the vertex. In order to maintain isofocality of the collector mirror, or to keep the latter isothermal with reference to its optical properties, it need only be ensured that the change in spacing Δa_1 is set in such a way as to result in the desired isofocal family of ellipses with the same optical effects resulting therefrom. The required change in spacing can, however, be determined either computationally or empirically from a knowledge of the materials used, the coefficients of expansion, the focal point spacings and further known parameters.

Under thermal loading, the collector mirror 1 should execute a displacement along the z-axis, that is to say the intercept distance must change. It is also advantageous for this purpose to mount the mirror in the plane 15 of the source 2. In the event of thermal expansion, it then automatically executes a movement against the z-axis 8. The ellipses then differ from one another only in the image scale of the source image or in the "relative aperture" of the aperture "on the image side". Such a change in the image scale is slight, however, and generally has only a negligible influence on

the performance of the illuminating system.

If the passive design does not suffice, the z-displacement can be set more accurately by means of suitable materials in the mount or between the mount 10 and the collector mirror 1 or the bearing 9. This can be performed, for example, by means of a suspension via bending elements 16 (see figure 5), or else by means of one or more active components 17 (see figure 6). The active components 17 can be arranged between the collector mirror 1 and the mount 10. Use may be made as active components of, for example, materials with specific expansion coefficients, in order to achieve the required longitudinal displacement. Also possible likewise, are purely active actuating elements such as, for example, pneumatic, hydraulic, magnetostatic, piezoelectric elements and the like. Such active elements have the advantage that they can be driven specifically and, if required, also with appropriate adaptations and changes.

A type of bearing for an isofocal collector mirror 1 is illustrated in figure 7, its "natural" displacement Δa_1 additionally further being amplified. For this purpose, a plurality of struts 18 are arranged from the collector mirror 1 in a fashion distributed over the circumference. They are located in this case in a circumferential region between the z-axis 8 and the outer circumference. The struts 18 are connected at one end to the collector mirror 1 via a fulcrum 19 in each case, while the other end is respectively supported in an articulated fashion at a bearing point 20 in each case. The longitudinal axes of the struts 18 extend parallel to the z-axis 8. If the collector mirror 1 now experiences a temperature rise, it expands and reaches the dashed position. At the same time, the struts 18 are also displaced thereby, and their fulcrums are displaced into the dashed positions 18′ and 19′, as a result of which the distance of the source 2 from the

vertex of the collector mirror 1 additionally changes further by the value Δa_x. The total displacement of the collector mirror 1 is therefore $\Delta a_2 = \Delta a_1 + \Delta a_x$. Δa_z can be set as desired via the lengths L of the struts 18 so as to achieve the isofocality.

The outward pivoting of the struts 18 produces a corresponding shortening with reference to the projection onto the z-axis, and thus additional path Δa_x.

The principle of a refinement is illustrated in figure 8, the inverse behavior being achieved. In this case, struts 18 likewise distributed over the circumference are provided, being situated between the z-axis 8 and the outer circumference of the collector mirror 1 and likewise being connected at one end to the collector mirror 1 via an articulation 19 in each case, and being mounted with the other end in a bearing point 20.

The longitudinal axes of the struts 18 are, however, arranged in this case obliquely relative to the z-axis in such a way that given a rearward displacement of the collector mirror 1 the struts 18 counteract this displacement, specifically by a measure Δa_x, in turn. In this case, it holds that $\Delta a_3 = \Delta a_1 - \Delta a_x$ for the displacement of the collector mirror 1. Here, as well, Δa_x can be set via the lengths L of the struts 18, and it is possible thereby to achieve a corresponding total displacement of the collector mirror 1 in such a way as to produce isofocality.

Whether to select the refinement according to figure 7 with the increase in the total displacement distance, or in accordance with figure 8 with the reduction in the total displacement distance, is determined in each case by the specific conditions of use and parameters.

A type of bearing for the collector mirror 1 is illus-

trated in principle in figure 9, the bearing being performed with the aid of the mount 10 via a parallelogram 21.

If required, it is also possible further to provide various transformation ratios in order to achieve the desired isofocality of 8 the collector mirror 1.

If appropriate, it is also additionally possible to make further provision of a cooling device, which is indicated only in principle in figure 4 with the aid of the reference numeral "22". Since, in particular when used with laser plasma sources, collector mirrors 1 are heated nonuniformally in a fashion distributed over the circumference, the cooling ducts 22 are to be arranged such that local cooling can be carried out in such a way that, when seen overall, an at least largely uniform temperature results for the collector mirror 1.

In the event of temperature increase, displacement of the collector mirror 1 also produces a variation in the magnification factor - although only to a slight extent.

Figures 10 and 11 show a collector mirror designed as a transmitted-light collector 1′ which has a multiplicity of nested mirror annular shells 23, termed annular shells below, which are connected on one side or in a floating fashion via a bearing, explained in yet more detail below of a flange ring 24 on the side averted from the light source 2. In a departure from the exemplary embodiment according to figure 1, in the case of the transmitted-light collector 1′ the light source 2 is located on the other side of the mirror 1, that is to say upstream in the beam direction (see also figure 10). There is provision in the exemplary embodiment illustrated of, for example, seven annular shells 23 via which the beams 25 generated by the light source 2 are passed on to a second focus. For reasons of clarity,

only two beams 25 are illustrated here. A transmitted-light collector 1' having only one annular shell 23 is also possible in principle.

Instead of the annular shells 23 being supported on one side or in a floating fashion in the flange ring 24 on the side averted from the light source 2, the annular shells 23 can also be connected to the flange ring 24 in the region between the two ends. In this case, axial displacements are possible at both ends of the annular shells 23 in the event of temperature deviations. Of course, it is also possible for the annular shells 23 to be supported in the flange ring 24 on the side facing the light source 2.

It may be seen from figure 11 and from the enlarged illustration in figure 12 that the flange ring 24 has four radially running strengthening ribs 26 in which the annular shells 23 are clamped or supported. As can further be seen from figures 10 and 11, the central area of the collector mirror 1' is occluded by a cover plate 27. Instead of four strengthening ribs 26, it is also possible, if appropriate, to provide only one rib or else a plurality of strengthening ribs.

As can be seen in figure 12, the flange ring 24 has cutouts in the form of slots 28 running in the circumferential direction in the region of the joining points of the strengthening ribs 26. The slots 28 extend by a multiple of the rib thickness in a circumferential direction, it being possible for the length of these slots 28 to be eight to ten times the thickness of a strengthening rib, for example. The longitudinal slots 28 serve only to decouple the strengthening ribs 26 from thermal stresses when different thermal expansions occur because of heating. The longitudinal slots 28 can give rise to linear expansions of the strengthening ribs 26, since owing to the slots 28 only a small thickness of material remains in the transition region

to the mounting ring 24 in the region of the joining points, and so the elastic movements are possible.

The bearings 29 or bearing points in the form of bores or holders may be seen in figure 12. The precise configuration of the bearings 29 or holders, and of the annular shells 23 will be described in more detail in the following figures.

Figure 13 shows the layout of a bearing, similar to the bearing according to figure 9, via a parallelogram 30 with two limbs 31, 32 which are arranged parallel to one another and are respectively connected at their ends via an articulation 33 to the mounting ring 24 or the ribs 26 and to a bearing part 34. An annular shell 23 is respectively held with its end in a bearing part 34 in any desired way, for example by welding, bonding or clamping. The respective other ends of the annular shells 23 are free, and so they can move freely in the event of temperature changes, in particular in the direction of the optical axis 35.

As is illustrated by dashes in figure 13, because of its articulated connection 33 the parallelogram 30 permits displacements of the annular shell 23 in the direction of the arrow 36 and thus perpendicular to the optical axis 35. At the same time, slight displacements in the direction of the optical axis are also additionally further possible in this case.

Figure 14 shows a configuration of the parallelogram 30 with its two limbs 31 and 32 in a monolithic design with the bearing part 34 and the rib 26, which forms, in turn, one piece with the mounting ring 24. The articulations 33 are formed by reductions in thickness at the ends of the limbs 31 and 32. The parallelogram 30 according to figure 14 can be produced in a desired way, for example by milling, sawing or via erosion/cavity sinking.

Figure 15 shows an exemplary embodiment with a bearing part 34 which is displaceable in the direction of the arrow 36 by means of a linear guide. Provided for this purpose is a guide 37 which is connecting to the bearing part 34 and is linearly displaceable in the direction of the arrow 36 in a bearing pin 38 with the aid of a linear guide. The bearing pin 38 is respectively supported in the associated strengthening rib 26.

Figures 16 to 18 show an embodiment of the bearing of the annular shells 23 in the strengthening ribs 26 via leaf springs 39. The leaf springs 39 are respectively shaped in this case from the annular shells 23 themselves in the region of the bearing points of the annular shells 23 at the strengthening ribs 26. One possibility for this is to introduce slots or cuts 40 which are arranged at a spacing from one another and form the leaf springs 39 between themselves. In the figures 16 to 18, the cuts 40 are introduced parallel to the optical axis 35, as may be seen from the illustration in figure 17, viewed from the direction of the arrow in figure 16. Likewise on the basis of their elasticity, the leaf springs 39 permit displacements of the annular shells 23 perpendicular to the optical axis (arrow direction 36), and can be connected in any desired way to the strengthening ribs 26. This can be performed, for example, by bonding, welding or clamping.

Figures 19 and 20 show an embodiment similar to the type illustrated in figures 16 to 18. The sole difference consists merely in that in this case the leaf springs 39 are not formed by cuts in the annular shells 23, but that separate leaf springs 39 are provided which are connected to the annular shells 23 in the region of the strengthening ribs 26 by means of bonding, soldering, welding or in any other desired way. Here, as well, the free ends of the leaf springs 39 can be connected to the strengthening ribs 26 by being

clamped, bonded or welded into slots in the said ribs.

Figures 21 to 24 likewise show an embodiment with leaf springs 39 via which the annular shells 23 are connected to the strengthening ribs 26. Instead of leaf springs 39 arranged according to figures 16 to 20 axially or parallel to the optical axis, these are arranged azimuthally or in a circumferential direction and thus perpendicular to the optical axis.

Figures 22 and 23 show the formation of the leaf springs 39 by means of an L-shaped incision in the annular shell 23. The shorter limb of the "L" runs in an axial direction, while the longer section of the "L" runs in a circumferential direction. Figure 22 likewise illustrates a view from the arrow direction Y of figure 21, the arrow direction Y simultaneously also illustrating the arrow direction 36 and thus the direction of movement of the annular shell 23.

Figure 24 corresponds to the illustration in figure 23, although in this case the leaf spring 39 is not formed from the annular shell 23 but, as with the exemplary embodiment according to figures 19 and 20, by a separate leaf spring 39 which is connected to an annular shell 23 by bonding, soldering, welding or else any other desired way.

In figures 21 and 24, the free end of the leaf spring 39 is likewise connected respectively to the strengthening ribs 26 by bonding, soldering, welding or in any other desired way.

Illustrated below in principle with the aid of figures 25 and 26 are two possibilities as to how to use active concepts to implement the required possibility for displacing the annular shells 23 in a direction perpendicular to the optical axis. Active concepts have the advantage that the rigidity of the overall system is

not negatively influenced by low rigidities such as are required by the passive concepts explained above. Rather, active concepts aim to bring the clamping points of the annular shells 23 in the strengthening ribs 26 to the positions at which they should be located in an ideal fashion at a specific temperature.

Figure 25 illustrates one possibility, the bearing part 34 in which the annular shell 23 is held being designed with regard to material and/or coefficient of thermal expansion and fixing of the length L such that by an appropriate optimization the bearing shell 34 moves in the arrow direction 36 and thus perpendicular to the optical axis in such a way that the optical properties of the collector mirror 1′ remain at least approximately the same in the event of temperature changes. In this case, the bearing part 34 is therefore connected permanently to the strengthening rib 26 on the inside.

Of course, it is not absolutely necessary for the bearing part 34 as a whole to be designed as a "thermal actuator" with the appropriate material, the coefficient of thermal expansion and the required length, but this can also be performed by a separate part 34′ as active adjusting unit which is connected to the bearing part 34. This is illustrated by the dashed line in figure 25. In this case, the separate part 34′ is connected to the strengthening rib 36. Instead of the thermal actuator illustrated in figure 25, other active adjusting units, which act on the bearing part 34 and adjust the latter in the direction of the arrow 36, are also possible.

It is also possible for the previously described passive systems additionally to be equipped with an active actuator, and this permits a combination of active and passive adjustment of the annular shells 23. A quasi-static and also a dynamic behavior can be influenced in a targeted fashion by an appropriate choice of the type

and position of such actuators in conjunction with sensors and the corresponding design of a control loop. Thus, however, active damping can be created or else the rigidity is selected as a function of frequency. It can, for example, be selected to be low in the case of low frequencies (thermal drift), and high in the case of rapid, for example mechanical vibrations. Also conceivable is an arrangement of actuators in conjunction with corresponding sensors which always ensure an ideal circular shape of the annular shell 23 by forming the difference between the sensor values.

A combination between a passive element and an active adjusting unit is illustrated merely in terms of principle in figure 26. As may be seen, the passive element corresponds to the parallelogram 30 according to figure 13. In addition, an actuator 40 (not illustrated in more detail) further acts on the bearing part 34 as active adjusting unit which, in the event of temperature changes, ensures that the bearing piece 34 and thus the annular shell 23 held in it are moved in the arrow direction 36 into a position in which the annular shell 23 experiences the smallest deformations.

The most varied embodiments are possible for active adjusting units such as, for example, pulling wires, push rods, piezoelectric elements, electric, electromagnetic systems and similar units. Such active adjusting units can be used separately, or else in combination with passive elements. Only the longitudinally adjustable plunger 41 of telescopic design is indicated with the aid of dashes in figure 26. An actuation device (not illustrated) can be used to adjust the length of the plunger 41, displacements in the bearing part 34 in the arrow direction 36 occurring as a result.

Since the second focus would not always remain at the same point in each case in the event of changes in shape or displacements of the annular shells 23, it can

be advantageous when, as indicated in figure 2 by the arrow 42, the light source 2 is appropriately displaced on the optical axis 35 in order to maintain the second focus. The displacement of the light source 2 in the arrow direction 42 can be performed by any desired devices (not illustrated here).